Reg Environ Change (2016) 16:1215–1224
DOI 10.1007/s10113-015-0842-x

ORIGINAL ARTICLE

Evidence and perceptions of rainfall change in Malawi: Do maize cultivar choices enhance climate change adaptation in sub-Saharan Africa?

Chloe Sutcliffe[1] · Andrew J. Dougill[1] · Claire H. Quinn[1]

Received: 31 October 2014 / Accepted: 11 July 2015 / Published online: 4 August 2015

Abstract Getting farmers to adopt new cultivars with greater tolerance for coping with climatic extremes and variability is considered as one way of adapting agricultural production to climate change. However, for successful adaptation to occur, an accurate recognition and understanding of the climate signal by key stakeholders (farmers, seed suppliers and agricultural extension services) is an essential precursor. This paper presents evidence based on fieldwork with smallholder maize producers and national seed network stakeholders in Malawi from 2010 to 2011, assessing understandings of rainfall changes and decision-making about maize cultivar choices. Our findings show that preferences for short-season maize cultivars are increasing based on perceptions that season lengths are growing shorter due to climate change and the assumption that growing shorter-season crops represents a good strategy for adapting to drought. However, meteorological records for the two study areas present no evidence for shortening seasons (or any significant change to rainfall characteristics), suggesting that short-season cultivars may not be the most suitable adaptation option for these areas. This demonstrates the dangers of oversimplified climate information in guiding changes in farmer decision-making about cultivar choice.

Keywords Dryland agriculture · Seed choices · Climate change

Editor: James D. Ford.

✉ Chloe Sutcliffe
chloesutcliffe@hotmail.com

Andrew J. Dougill
a.j.dougill@leeds.ac.uk

Claire H. Quinn
c.h.quinn@leeds.ac.uk

[1] Sustainability Research Institute, University of Leeds, Leeds, UK

Introduction

The significant threat which climate change poses to agricultural production and food security in sub-Saharan Africa is now widely recognised (Calzadilla et al. 2013; IPCC 2014; Challinor et al. 2014). Whilst predictions of rainfall impacts in much of sub-Saharan Africa remain uncertain, there is medium confidence that Southern Africa will receive a reduction in rainfall by the end of this century and Eastern Africa will experience increasing precipitation extremes, with high confidence that continued temperature increases across the continent will occur leading to greater water stress (Christensen et al. 2013).

Regional assessments of climate vulnerability (Davies and Midgley 2010; Davis 2011; Abson et al. 2012) have highlighted Malawi's high levels of climate risk and associated food system insecurity. These result from its high population density, heavy dependence on rain-fed agriculture and high variability of wet season rainfall (McSweeney et al. 2012). Regional projections for Southern Africa assert that Malawi will warm, but greater uncertainties exist around rainfall projections (IPCC 2014).

In view of the likely impacts of climate change, the great importance of adaptation ('adjustment to actual or expected climate and its effects' IPCC 2014) is broadly recognised. However, given the uncertainties that exist around down-scaled climate projections, the need to carefully consider how near-term or incremental adaptations may facilitate or hinder larger-scale, longer-term adaptations in the future has been underlined (Rickards and Howden 2012).

Cultivar change (which features as a priority strategy within the NAPAs of various nations in SSA) is an incremental adaptation with the potential to strengthen or undermine climate resilience within agricultural systems (Cooper et al. 2008). A number of international initiatives (Toenniessen et al. 2008; Yuksel 2008; Hemming 2008; Cooper and Cappiello 2012) are now focussed on providing improved cultivars for major crops in order to address some of SSA's key agricultural problems (soil degradation, inadequate or incorrect inputs usage and climate variability Sanchez 2002; Mafongoya et al. 2006; Challinor et al. 2007), as well as the likely exacerbating effects of climate change upon them. Breeding and distributing maize cultivars with increased drought tolerance is a prime concern (Hemming 2008), with some arguing that breeding cultivars likely to be suitable for future climates should be undertaken now to prepare for the more challenging climate impacts that have been predicted (Cairns et al. 2013). Enabling the adoption of improved seeds, however, not only concerns the specific traits of newly released cultivars, but is also dependent on how they are marketed (Shiferaw et al. 2011) and explained to smallholder farmers (Whitfield and Kristjanson). Seed systems in SSA, traditionally dominated by parastatals and farmer-saved varieties, have been undergoing a transformation (Tripp and Rohrbach 2001). The power of commercial players has been massively invigorated following market liberalisation, with global agri-businesses taking the helm as providers of the types of seed (mainly hybrid) they see as best suited to moving African agriculture forwards (Mccann 2011). New alliances between the public and private domains of national African seed systems are being formed in the hope that corporate actors will also work to realise development and adaptation goals (Scoones and Thompson 2011; Chinsinga 2011).

Work examining barriers and limits to climate change adaptation has been gaining momentum over the last decade (Dessai et al. 2004; Jones and Boyd 2011; Adger et al. 2009). A key initial barrier to effective adaptation is the failure to accurately perceive a climate signal or to recognise its significance (Moser and Ekstrom 2010), with implications for whether an adaptation response occurs at all, and/or for the type of adaptation response that is chosen. However, climate signal perception is complicated by a range of factors including population exposure and livelihood sensitivity to that signal, culturally determined attitudes to risk, and dominant narratives concerning environmental change. Farmers may only perceive changes to rainfall if they occur at critical points within the growing season (Ovuka and Lindqvist 2000), broader narratives of environmental change may shape perceptions regardless of their accuracy (Fairhead and Leach 1996; Mertz et al. 2009), and different groups may disagree on the seriousness of risks from climate impacts, with implications for whether or not adaptations are undertaken (Patt and Schroter 2008; Brooks et al. 2009).

In recent years, papers exploring perceptions of climate change amongst African agriculturists have proliferated. A number of these papers explore adaptation strategies and link these to local perceptions of climate change but do not establish the degree to which perceptions agree with meteorological data (Silvestri et al. 2012; Yaro 2013). Establishing the latter is important because a number of studies have revealed that local perceptions of climate trends can be poorly reflected by meteorological records. In Ethiopia, Meze-Hausken (2004) found no evidence to support farmers' and pastoralists' claims that rains were becoming less reliable. In Kenya, Rao et al. (2011) found that agriculturists had a limited ability to discern long-term climatic trends and overestimated the incidence of hazardous climatic events. Similarly, in Uganda, Osbahr et al. (2011) found no evidence of changing rainfall patterns despite farmers' suggestions that the variability of the rains had increased. In Botswana and Malawi, Simelton et al. (2013) found little support within historical precipitation patterns for farmers' suggestions that seasons previously used to start earlier than they do now. These studies, however, do not focus on the implications of their findings for adaptation pathways (but see Zampaligre et al. 2014).

This study contributes to this field by exploring links between climate perceptions and rainfall records and their implications for the potential success of a single adaptation strategy (maize cultivar change). It is situated within the context of Malawi's modernising national seed system and its transformation by forces such as the growth of corporate seed industry power and the operation of the government's agricultural input subsidy programme (AISP). Specifically, this paper addresses the following three objectives:

1. It explores the perceptions and understandings of changes to seasonal weather and 'climate change' held by stakeholders included in the study, and their implications in terms of maize breeding priorities
2. It describes cultivar provision and preferences in the two research areas where fieldwork was carried out
3. And it assesses the meteorological evidence for changing seasonal rainfall in each of the study areas

Methods

Research was undertaken with smallholder maize producers in two rural areas of Malawi in 2010 and 2011. In addition, semi-structured interviews were held with stakeholders from within Malawi's national seed system including agricultural extension workers, NGO staff, national research and seed breeding staff, and managers from private sector maize seed companies. Two research areas were studied with contrasting productive potential for maize, different degrees of susceptibility to the types of climate hazard likely to be associated with climate change, and with a strong reliance on maize as the dietary staple. A second selection criterion was that rainfall and temperature records could be obtained from a meteorological station located close to the research villages, enabling a comparison between records and perceptions of historical changes to seasonal conditions.

The rural outskirts of Ngabu Town in the Lower Shire Valley were selected as the first area. Ngabu is considered highly vulnerable to climate hazards and is correspondingly food insecure, experiencing a high incidence of drought and flooding, and frequently requiring food aid (Phiri and Saka 2008; Madziakapita 2008). Its altitude averages 100 m above sea level (Chidanti-Malunga 2011) placing Ngabu in a lowland tropical zone with short growing seasons considered as marginal for maize cultivation (Heisey and Smale 1995). Average annual rainfall has been reported at 924 mm, but inter-annual variability is high (Wang et al. 2009). As well as cash-cropping cotton, farmers in the area produce maize, sorghum, millet, legumes, sweet potatoes and other vegetables. The local population relies heavily on millet and sorghum as staples, but strongly prefers to consume maize (Mandala 2005).

The Kasungu–Lilongwe Plain was selected as the second research area. Here, maize is often produced in surplus, and the production zone is considered to be characterised by longer growing seasons and cool temperatures (Heisey and Smale 1995). In addition to maize, tobacco is an important cash crop (Prowse 2009), but a wide range of other crops are also grown including vegetables, cassava and groundnut. The area is still vulnerable to drought and suffered severe yield losses in the 2002 famine and again in 2005 (Devereux et al. 2006; Kamkwamba and Mealer 2009). The district is mainly flat with an altitude of 1,342 m above sea level (Government of Malawi 2007). Rains in the area are generally considered to be good (Government of Malawi 2007), and an average of 805 mm has been reported to fall annually with a coefficient of variation of 23 % (Jones and Thornton 1997).

Research villages were selected based on the number of households they contained, willingness to participate in the research and their proximity to nearest rainfall station (<15 km). Two villages in Kasungu and three in Ngabu were included in the research. Data were collected from 266 households and individuals using questionnaires, participatory techniques, focus groups and semi-structured interviews. For the questionnaires, participants were randomly sampled in order to achieve a representative sample composition. Interview and focus group participants were then purposively selected based on their questionnaire responses. Seventeen semi-structured interviews were carried out with local extension workers and with stakeholders from within Malawi's seed industry. Daily rainfall data sets (from 1961 to 2011), collected at Kasungu Airport and at Ngabu Agricultural Research Station, were provided by Malawi Meteorological Services. Seasonal definitions were used following Tadross et al. (2007), such that rainy season onset was defined as the first instance when more than 25 mm of rainfall had accumulated over a period of 10 consecutive days, with no period of ten consecutive dry days (those receiving <2 mm of rainfall) occurring within the following 20 days. The end of the season was defined as the point when three consecutive 10 day periods each received less than 20 mm of rainfall after 1 February.

Quantitative socio-economic and meteorological data sets were analysed statistically using Excel 2010 and PASW18 (Allen and Bennett 2010), and qualitative material obtained from interviews and focus groups was analysed using thematic techniques and NVivo software (Gibbs 2002; Berg and Lune 2014).

Results

Perceptions and understandings of changes to seasonal weather, 'climate change' and implications for maize breeding

The majority of participants in the two sites perceived later rainy season onsets, shortening total season lengths and increasing problems with dry spells (Table 1).

The majority of questionnaire respondents reported experiencing increasing difficulties with maize production, often attributing this to a change in rainfall or climate. In Ngabu, 96.7 % perceived maize production as increasingly difficult, with 91.1 % of the total sample blaming poor rain or too much sun ($n = 123$). In Kasungu, attitudes were more divided. The majority (61.7 %) stated that it was getting harder to have a successful maize crop, and just under a quarter of the overall sample (24.7 %) attributed this to climatic problems [with a slightly larger proportion of respondents, 31.3 %, blaming their inability to access modern inputs ($n = 81$)]. Drought was a common concern, with nearly all participants defining drought as an extended dry spell that occurred during the growing season.

Smallholder participants commonly referred to perceived changes as climate change, but few understood 'climate change' as a global phenomenon. Participants described encountering the term 'climate change' through

Table 1 Comments from research participants about changes to seasonal rainfall in their local area, Kasungu and Ngabu, 2010 and 2011

Kasungu	The rainfall pattern is changing. We would expect it to start in October/November, but now the rains are starting in December
	Thirty years ago the rains would come maybe in October. Now the rains come late
	Previously the rains would end in maybe April or March, but now when it starts in December, by March they are gone
	Dry spells never used to happen thirty years ago, and today they are worse than they were fifteen years ago
Ngabu	The rains used to start in October, but these days they come in November
	These days the rain is coming late compared to the last years, because in previous seasons the rains would have already started and we would have planted by now. Today we don't even know any more when the rains will come. The rains used to start in September, but these days they don't start until November, December
	The rains come and the maize grows in the first place, but with time it stops. Usually the rains start in November and then they stop in December, maybe up until February, two months later

the radio, but attributed perceived seasonal changes to local environmental disturbances such as deforestation or the development of cement factories or sugar plantations.

In each area, local research and extension staff also reported perceiving changes to seasonal conditions. In Ngabu, increasingly erratic rains and longer droughts were reported. In Kasungu, extension workers confirmed that the area was currently experiencing a shorter period of rain, with some confusion over whether or not this change could be referred to as climate change.

> Because of the… can we say climate change? The Met people are refusing to call it that, we have to… Sorry! I don't know what we can call it! But we have been experiencing a short period of rain. The rainy days have been growing maybe shorter and shorter as compared to the past seasons. So we are recommending early-maturing varieties.
> Extension manager, Kasungu, summer 2011

National actors within the seed system also considered rainfall characteristics to have changed at a country-wide level in terms of season length, timing and the incidence of dry spells. Stakeholders throughout the seed system raised concerns about drought, and there was broad agreement on the need to produce better adapted maize cultivars. However, there was disagreement on the specific meaning of drought tolerance as a cultivar trait. Whilst the public sector maize breeders interviewed understood 'drought' as a difficult term to define and distinguished between traits of early maturity (as capacity to escape from drought) and drought tolerance (as capacity to withstand low moisture availability during the growing season), participants from private industry felt that drought tolerance and early maturity were essentially the same:

> Our definition of drought, it's really, okay, so let's come up with varieties which should be drought tolerant. What do we mean? We mean the variety which is still going to, in 90 days, if you plant it, it will still give you something.
> Seed company manager A, summer 2011

Whilst seed company participants indicated concerns about climate change, they reported referring to few sources of information about impacts projections, relying predominantly on communications from Malawi Meteorological Services. Producing cultivars with traits adapted to potential future climates was not a breeding concern. No breeding specifically for drought tolerance by withholding irrigation under controlled conditions was being undertaken. Instead, observations of rain-fed field conditions predominated, with one participant observing that:

> …It's a difficult one, like if there's a drought site that is under stress then obviously we can test for it, but it's not like we go and plant them indoors and only water some, we haven't got to that stage yet…. We are hedging our bets anyway, but I wouldn't say there's specific planning for climate change.
> Seed company manager B, summer 2011

In contrast to the participants from public sector breeding organisations, corporate breeding programmes more strongly emphasised early maturity, indicating that the production of short-season cultivars was a good commercial strategy due to their marketability across a wider geographic range than longer-maturing cultivars. One corporate participant suggested that the state-run agricultural input subsidy programme (AISP) made this type of approach more attractive:

> Because with the subsidy programme, sometimes you have to give varieties which are suitable in most all the places.
> Seed company manager C

To summarise, changes to seasonal rainfall characteristics were perceived from the local to national level. These changes were referred to as climate change, although global 'climate change' was poorly understood at the local level. All seed system actors recognised a need for better adapted cultivars to cope with climate change and drought, but corporate seed companies were not expressly breeding for this. Corporate and public sector viewpoints on

Table 2 Maize cultivar traits considered the most important by questionnaire respondents in Kasungu and Ngabu, 2010

Cultivar characteristic	Kasungu		Ngabu	
	Percentage mentioning this characteristic	Number of responses	Percentage mentioning this characteristic	Number of responses
Good storage	38.3	31	0	–
Early maturity	34.6	28	72.7	88
Pest resistance	21.0	17	0	–
High yield	14.8	12	7.4	9
Large grains	9.9	8	11.6	14

drought-resistant cultivar traits differed. Corporate actors strongly prioritised early maturity despite this trait not being considered as true drought tolerance by those in the public sector.

Cultivar provision, preference and use in the research areas

A leading maize seed breeder within the national programme stated that only the fastest maturing cultivars were suitable for Ngabu, but that in Kasungu, higher yields are achievable using longer-maturing cultivars. Despite this, early maturity was a popular trait in both areas; In Ngabu, it was by far the most popular trait, whilst in Kasungu, it was the second most popular (Table 2).

Hybrid, corporate brand, short-season cultivars were widely cultivated in both areas in 2011, whilst open-pollinated, public good cultivars[1] bred specifically for drought tolerance featured considerably less. In Ngabu, only 6.0 % of households reported having cultivated drought-tolerant public good varieties (which reflected the fact that these cultivars were not made available under the AISP in the area), but a much higher proportion reported using corporate brand short-season cultivars (71.4 %) ($n = 83$). Proportions using public good drought-tolerant cultivars were higher in Kasungu (as a result of their widespread availability through the AISP), at 31.8 %. Nonetheless, a higher proportion of households were cultivating corporate brand short-season cultivars (47.7 %) ($n = 107$).

These use patterns largely reflected the market availability of cultivar types in seed outlets in each of the towns, where corporate brand cultivars (in particular short- and ultra-short-season ones) dominated available supplies. In both areas, short-season cultivars were commonly available in a range of pack sizes, including smaller pack size options of one and two kilograms which are more attractive to poorer smallholders. Comparatively, small pack sizes for longer-season cultivars had limited availability. Only one of the five participating seed outlets in Ngabu reported having a public good cultivar available for purchase, and the same was true for only two out of eight of the participating seed outlets in Kasungu (Table 3).

The market dominance of corporate brand, short-season cultivars in both areas was thus clearly evident, and this was reflected by the seed use patterns reported by questionnaire respondents and the cultivar trait preferences they described.

Evidence of changing seasonal rainfall within local meteorological records

Whilst high variability was evident in the rainfall records for the two locations, no evidence of any overall change to the rainy season in terms of onset, season length or dry spells was found.

Slightly higher variation of onset was experienced in both locations in the 1990s, but with no overall trend (Fig. 1).

Season length was determined by working out the difference between rainy season onset and the end of the season (Tadross et al. 2007). Again, no trend was discernible in either area, although greater variability was evident in Ngabu, with some seasons in the record (such as 1992) failing entirely from the point of view of maize production (Fig. 2).

Since several research participants highlighted flowering as the time of greatest vulnerability to dry spells, analysis investigated dry spells that occurred during this period (between days 40 and 85 after the season commenced). Whilst the incidence of dry spells during this period showed considerable variability in both areas, with a tendency for much longer dry spells to be

[1] Public good cultivars are those bred by state or non-governmental organisations over which exclusive breeding rights are not asserted. As discussed, public good breeders have concentrated more on breeding for drought stress tolerance, whereas early maturity has been considered as a more important breeding trait by corporate companies.

Table 3 Availability of cultivar brands from local outlets in Ngabu and Kasungu in 2011

Cultivar name	Duration	Number of outlets which stocked cultivar in 2010–2011 season	
		Ngabu ($n = 5$)	Kasungu ($n = 7$)
Kanyani (SC403)	Ultra-short-season hybrid (90–95 days)	5 (100 %)	7 (100 %)
DK8033	Short-season hybrid (110–115 days)	4 (80 %)	7 (100 %)
Pan 67	Medium-season hybrid (120–130 days)	3 (60 %)	4 (57 %)
DK 8031	Early-season hybrid (equivalent to DK 8033)	2 (40 %)	1 (14 %)
DK 8053	Medium-season hybrid (130–135 days)	1 (20 %)	4 (57 %)
DK 8073	Long-season hybrid (140–145 days)	0	5 (71 %)
Pan 53	Medium-season hybrid (125–135 days)	0	4 (57 %)
Mkango (SC627)	Medium-season hybrid (info on days unavailable)	0	3 (42 %)
Njobvu (SC719)	Long-season hybrid (info on days unavailable)	0	2 (28 %)
ZM range of cultivars	Drought-tolerant short–medium-season OPVs	1 (20 %)	2 (25 %)

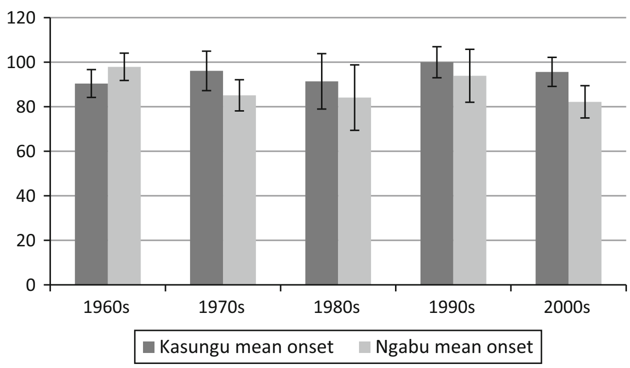


Fig. 1 Mean rainy season onset by decade for Ngabu and Kasungu (*error bars* = SD, day 20 is 20 September)

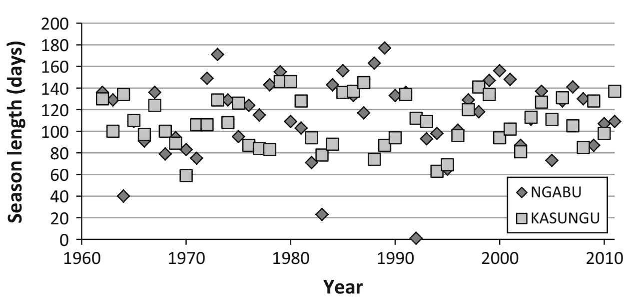


Fig. 2 Season length by year, Kasungu and Ngabu

experienced in Ngabu than in Kasungu, there was again no discernible trend for increasing dry spells in either area (Fig. 3).

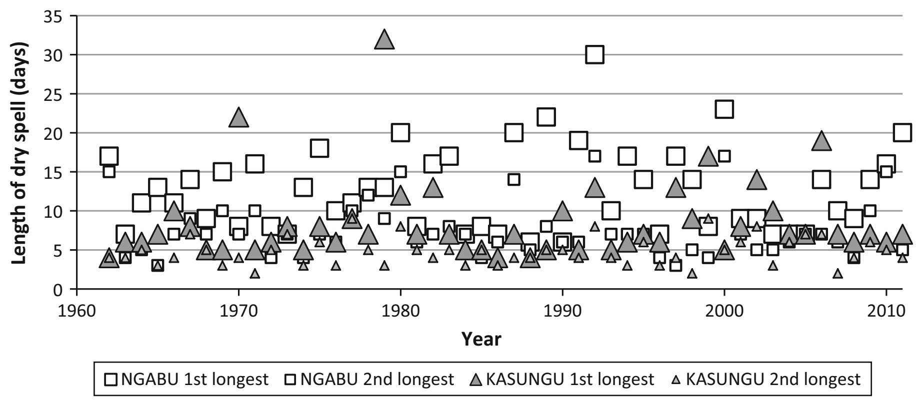
To conclude, despite widespread perceptions that seasonal rainfall characteristics have changed, which were reflected in preferences for shorter-season cultivars, no evidence of change in the rainfall record for either research location could be found.

Discussion

The results presented lead to a number of further questions which cannot be answered definitively based on the available data but provide food for discussion. Firstly, the findings complement a number of other studies undertaken in highly variable climatic environments in SSA that have also found a mismatch between local perceptions of changing climatic conditions and the evidence within historical meteorological data (Meze-Hausken 2004; Osbahr et al. 2011; Rao et al. 2011; Simelton et al. 2013). This leads to the question of why perceptions of rainfall change might not find support within the meteorological data. Assuming that rainfall has not been mismeasured, it would be reductive to suggest that the mismatch is caused by error on either side (Meze-Hausken 2004). The perceptions themselves are likely to have a solid basis, if not in the rainfall data then either in other meteorological data not included in the analysis, or in changes to other factors affecting the experiences of agricultural producers (Simelton et al. 2013; Osbahr et al. 2011; Meze-Hausken 2004).

The meteorological analysis conducted by the authors was limited by the fact that agro-meteorological data covering other potentially significant production factors (such as wind speed, sunlight and soil water content) were unavailable. Additionally, no historical yield data were available for either research area, meaning that it was impossible to evaluate historical maize production trends or to perform a cross-analysis determining links with historical seasonal rainfall patterns. Because agriculturists are likely to base their assumptions about seasonal rainfall on their observations of production outcomes (rather than purely on first-hand observations of that rainfall, as would be the case for meteorologists), their perceptions are a product of complex combinations of the many various

Fig. 3 Length of first and second longest dry spell between days 40 and 85 of the growing season, Kasungu and Ngabu



factors influencing yields. In addition to changing environmental determinants such as pests and diseases, weed competition, soil structure and fertility, as well as changing agricultural factors such as cultivation techniques, inputs usage and changing crop combinations and germplasm, production is also influenced by changes to socio-economic, political and health factors that determine the availability of agricultural labour and change expectations about agricultural production over time (Simelton et al. 2013). It is also notable that agricultural and meteorological definitions of drought differ substantially (Glantz and Katz 1977). In this vein, climate is defined by meteorologists as average weather over (at least) a 30-year period (IPCC 2014). Human memory, by contrast, is subjective and subject to bias leading to the overemphasis of climatic events that coincide with other significant experiences (Osbahr et al. 2011) and the tendency to overemphasize negative climate events (Rao et al. 2011).

Malawi's agricultural history has been strongly influenced by national political changes and can be characterised by mercurial support for smallholder agricultural production (Harrigan 2003). President Hastings Banda's early rule featured campaigns of state promotion of modern agricultural inputs (via subsidies) as well as control over maize prices through the parastatal maize marketing board (Allcock and Kainja 2011). However, initial economic growth later faltered inducing the acceptance of structural adjustment programming, conditional upon market liberalisation (Harrigan 2003). This saw the removal of subsidies causing inputs to become unaffordable for many, and the nation became increasingly food insecure. Following transition from dictatorial rule to a multi-party system of governance, economic decline continued and a major national food crisis was experienced in 2002 (Devereux 2002). Agricultural subsidies were re-introduced and currently take the form of the AISP (agricultural input subsidy programme), which has become highly politicised (Chinsinga 2011). Liberalisation and the AISP-boosted inputs market have attracted participation by powerful international agribusiness which has transformed the range of maize cultivars being marketed to smallholders as well as effected their commodification. Vis-a-vis these corporations, public sector players have little marketing power and increasingly the multiplication and sale of public good cultivars is left to the discretion of private business players. Meanwhile, other influential factors including increasing population pressure on land for farming, changing regulatory environments for cash crop production, waves of temporary migration to South Africa and health epidemics such as HIV (Frankenburger et al. 2003; Bryceson 2006) have all impacted on agricultural productivity. Simelton et al. (2013, p. 134) show that in Malawi, the inter-annual variability of rainfall has become increasingly uncoupled from the inter-annual variability of maize productivity over the last two decades, which is likely attributable to the combined effect of all the factors just discussed.

Within the research contexts some specific explanations for the mismatch between local perceptions and the meteorological rainfall records can be proposed. In Ngabu, maize production has historically been tenuous and millet and sorghum have predominated as subsistence staples (Mandala 2005). However, a powerful national narrative links maize consumption with food security (Smale 1995). This, coupled with provision of government subsidies for maize inputs in the area, may underlie misguided beliefs that summer maize production should be feasible. Whilst perceptions of rainfall change were more unified in Ngabu than in Kasungu (perhaps because of harsh local production conditions), perceptions of change in Kasungu were also widespread, possibly due to memories of the famine in 2002 which claimed several hundred lives in the area (Kamkwamba and Mealer 2009; Devereux 2002). However, the famine itself was a product of complex factors affecting national food security overall, including the sale of the strategic grain reserve (Devereux 2002). The rainfall records show that in other years, similar rainfall distributions have been experienced without such dramatic consequences.

Because analysis of the rainfall data has failed to provide support for perceptions that seasons are shortening, the suitability of short-season cultivars as an adaptation strategy is questionable. This question echoes the doubts that were voiced by public sector maize providers about the suitability of using short-season cultivars as a strategy for adapting to drought. However, corporate seed providers were happy that short-season cultivars provided good drought protection. Thus, a second question arising from the findings is about why perspectives on the suitability of short-season maize cultivars should differ between public and private sector maize providers and about the implications of this for adaptation goals. Since profit is the bottom line for corporate actors, it is clear that promoting short-season hybrid cultivars which need to be purchased afresh every year and are suitable for use across a broad geographic range makes business sense. Public breeders on the other hand are not as constrained by commercial considerations and are more likely to engage with international donors and programmes such as Drought-Tolerant Maize for Africa where the concept of ‘drought’ is problematised and international expertise on climate change is referred to. As such, their breeding goals may be more closely aligned with climate change adaptation considerations or geared to the needs of poorer smallholders who cannot afford to repeat purchases of hybrid maize annually. These different breeding motives should be considered in relation to the marketing power imbalance between public and corporate sector seed providers, since there is a clear danger that the dominance of the latter will continue, meaning that public sector cultivars expressly bred for drought tolerance and capacity to be recycled may remain under-promoted to smallholders. The modernisation of Malawi’s seed system has transformed the cultivar selection situation for farmers from one where on-farm seed saving ensured that germplasm co-evolved with local seasonal environmental conditions to one where farmers now rely on modern cultivars developed far away from their own fields. This means that it is now more important than ever that farmers use their observations of seasonal conditions and refer to external information such as seasonal forecasts to direct their choice of the modern cultivars they purchase. They must also engage increasingly with information about the range of cultivars on offer in shops. High levels of illiteracy amongst rural populations do not facilitate this. At the same time, the commodification of maize seed that has occurred over recent decades means that cultivar choice now operates as a social signifier denoting wealth, which adds to the attractiveness of hybrids for smallholders, whilst their desire to minimise production risks ensures the popularity of the shortest season hybrids available.

The fact that perceptions may poorly reflect underlying meteorological changes is a significant one to consider in relation to cultivar change for climate adaptation since misconceptions about the causes of changing production trends may lead to maladaptation. In this case, because season length appears to remain unchanged, higher yields may well be achievable via the cultivation of longer-maturing varieties bred to withstand dry spells, rather than those bred for early maturity. Over time, selecting shorter-season cultivars might mean that farmers forgo larger yields, thus reducing their resilience for coping with longer-term climate change and other livelihood stressors. Since rainfall has not clearly worsened over the last 50 years in either area, it is important that further research should be used to pinpoint whether other production features have changed significantly in order that these changes can be suitably addressed. In terms of preparing germplasm for adaptation to future climate change, because projected rainfall impacts in the region remain highly uncertain, but there is high confidence that temperatures will increase, breeding cultivars with enhanced temperature tolerance may represent a lower regret option (Cooper and Cappiello 2012). Researchers have claimed that the local cultivars traditionally grown by Malawian smallholder farmers prior to the advent of hybrid maize have particularly strong temperature tolerance (Magorokosho 2006), and areas of Malawi such as Ngabu provide an excellent climate analogue for locating breeding efforts geared towards developing temperature-tolerant strains. However, at present neither local cultivar germplasm nor areas in Malawi that could operate as high temperature analogues are being exploited to prepare new maize cultivars for the higher temperatures that climate change will bring.

Conclusion

This paper has reported on research investigating maize cultivar change as an incremental adaptation strategy amongst smallholder farmers in central and southern Malawi. Primary data were collected about maize cultivar use, preferences and availability and perceptions of changes to seasonal rainfall. Historic rainfall data sets from local meteorological stations were also analysed for evidence of trends. Widespread perceptions of changes to seasonal rainfall (shorter season length, later rainy season onset and increasingly intense dry spells) were found amongst both local and national agricultural stakeholders as well as broad concurrence that new, improved maize cultivars need to be adopted by farmers to respond to these changes and improve maize yields. However, disagreement was revealed between seed providers about how far short-season cultivars enable successful adaptation to drought. Corporate actors conflated drought escape and drought tolerance and prioritised breeding for early maturity, but public sector participants considered the two to be different and dedicated more resources to breeding specifically for water stress. This latter approach is now favoured within programmes that specifically seek to address water shortages (Brooks et al. 2009). Nonetheless, the results show that smallholders are more likely to access short-season cultivars than drought-tolerant ones because of the market dominance of corporate brands. Additionally, whilst the rainfall analysis undertaken reveals high variability of rainfall within the two research areas, it provides no evidence of significant changes to seasonal rainfall in support of the perceptions of change that many stakeholders expressed. The findings also reveal an imbalance of market power within the seed system, with short-season hybrid corporate cultivars predominating and drought-tolerant public goods cultivars being scarce.

These points of disagreement and imbalance within Malawi's maize seed climate nexus may lead to sub-optimal incremental adaptation choices in terms of cultivar change. Adopting new cultivars that are optimally suited to current climate conditions and readying cultivars with adaptations suitable for future conditions constitute incremental adaptations that should enhance resilience for coping with more serious climate impacts as climate change progresses. In order to facilitate this, it is essential that seed providers, farmers and meteorological and climate change specialists engage in clear dialogue about how local weather is changing and what crop traits will cope best. Partial knowledge and power imbalances within seed systems need to be addressed to enable the enhanced communication and understanding that will underpin successful agricultural adaptation to climate change. In the case of Malawi, corporate dominance within the seed system may mean that public sector adaptation goals fail to be effectively realised.

Acknowledgements This work was funded by the ESRC Centre for Climate Change Economics and Policy.

References

Abson DJ, Dougill AJ, Stringer LC (2012) Using principal component analysis for information-rich socio-ecological vulnerability mapping in Southern Africa. Appl Geogr 35:515–524

Adger WN, Dessai S, Goulden M, Hulme M, Lorenzoni I, Nelson DR, Naess LO, Wolf J, Wreford A (2009) Are there social limits to adaptation to climate change? Clim Change 93:335–354

Allcock L, Kainja J (2011) Reimagining 21st century development in Malawi: generating and sharing knowledge beyond the traditional development establishment. IDS Bull 42:99–103

Allen PJ, Bennett K (2010) PASW statistics by SPSS: a practical guide: version 18.0. Cengage Learning, South Melbourne

Berg L, Lune H (2014) Qualitative research methods for the social sciences. Pearson, Harlow

Brooks S, Thompson J, Odame H, Kibaara B, Nderitu S, Karin F, Millstone E (2009) Environmental change and maize innovation in Kenya: exploring pathways in and out of maize, STEPS Working Paper 36, STEPS Centre, Brighton

Bryceson DF (2006) Ganyu casual labour, famine and HIV/AIDS in rural Malawi: causality and casualty. J Mod Afr Stud 44:173–202

Cairns JE, Hellin J, Sonder K, Araus JL, Macrobert JF, Thierfelder C, Prasanna BM (2013) Adapting maize production to climate change in sub-Saharan Africa. Food Secur 5:345–360

Calzadilla A, Rehdanz K, Betts R, Falloon P, Wiltshire A, Tol RSJ (2013) Climate change impacts on global agriculture. Clim Change 120:357–374

Challinor A, Wheeler T, Garforth C, Craufurd P, Kassam A (2007) Assessing the vulnerability of food crop systems in Africa to climate change. Clim Change 83:381–399

Challinor AJ, Watson J, Lobell DB, Howden SM, Smith DR, Chhetri N (2014) A meta-analysis of crop yield under climate change and adaptation. Nat Clim Change 4:287–291

Chidanti-Malunga J (2011) Adaptive strategies to climate change in Southern Malawi. Phys Chem Earth 36:1043–1046

Chinsinga B (2011) Seeds and subsidies: the political economy of input programmes in Malawi. IDS Bull 42:59–68

Christensen JH, Krishna Kumar K, Aldrian E, An S-I, Cavalcanti IFA, De Castro M, Dong W, Goswami P, Hall A, Kanyanga JK, Kitoh A, Kossin J, Lau N-C, Renwick J, Stephen DB, Xie S-P, Zhou T (2013) Climate phenomena and their relevance for future regional climate change. In: Stocker TF, Qin D, Plattner G-K, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM (eds) Climate change 2013: the physical science basis. Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge

Cooper P, Cappiello SF (2012) Case studies: the large-scale implementation of adaptation and mitigation actions in the agriculture and food sector. Draft for discussion, CGIAR Research Program on Climate Change, Agriculture and Food Security

Cooper PJM, Dimes J, Rao KPC, Shapiro B, Shiferaw B, Twomlow S (2008) Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change? Agric Ecosyst Environ 126:24–35

Davies R, Midgley S (2010) Risk and vulnerability mapping in Southern Africa: a hotspot analysis. OneWorld Sustainable Investments (Pty) Ltd, Cape Town

Davis C (2011) Climate risk and vulnerability: a handbook for Southern Africa. Council for Scientific and Industrial Research, Pretoria **25**

Dessai S, Adger WN, Hulme M, Turnpenny J, Kohler J, Warren R (2004) Defining and experiencing dangerous climate change—an editorial essay. Clim Change 64:11–25

Devereux S (2002) The Malawi famine 2002. IDS Bull 33:70–78

Devereux S, Baulch B, Phiri A, Sabates-Wheeler R (2006) Vulnerability to chronic poverty and malnutrition in Malawi: a report to DFID Malawi, Lilongwe, Malawi

Fairhead J, Leach M (1996) Misreading the African landscape: society and ecology in a forest-savanna mosaic. Cambridge University Press

Frankenburger T, Luther K, Fox K, Mazzeo J (2003) Livelihood erosion through time: Macro and micro factors that influenced livelihood trends in Malawi over the last 30 years. CARE Southern and Western Africa Regional Management Unit (SWARMU)

Gibbs GR (2002) Qualitative data analysis: explorations with NVivo. Open University

Glantz MH, Katz RW (1977) When is a drought a drought? Nature 267(5608):192–193. doi:10.1038/267192a0

Government of Malawi (2007) Kasungu District: socioeconomic profile, Kasungu, Malawi

Harrigan J (2003) U-turns and full circles: two decades of agricultural reform in Malawi 1981–2000. World Dev 31:847–863

Heisey PW, Smale M (1995) Maize technology in Malawi: A green revolution in the making? CIMMYT, Mexico, DF

Hemming D (2008) AATF to develop drought-tolerant maize for Africa. Outlook Agric 37:145–146

IPCC (2014) Climate change 2014: impacts, adaptation and vulnerability. Cambridge University Press, Cambridge

Jones L, Boyd E (2011) Exploring social barriers to adaptation: insights from Western Nepal. Glob Environ Change Hum Policy Dimens 21:1262–1274

Jones PG, Thornton PK (1997) Spatial and temporal variability of rainfall related to a third-order Markov model. Agric For Meteorol 86:127–138

Kamkwamba W, Mealer B (2009) The boy who harnessed the wind. Harper Collins, London

Madziakapita A (2008) An evaluation of the impact of food aid on food security: the case of Ngabu Area in Malawi. ethesis, Department of Development Studies, University of South Africa

Mafongoya PL, Bationo A, Kihara J, Waswa BS (2006) Appropriate technologies to replenish soil fertility in southern Africa. Nutr Cycl Agroecosyst 76:137–151

Magorokosho C (2006) Genetic diversity and performance of maize varieties from Zimbabwe. Texas A&M University, Zambia

Mandala EC (2005) The end of chidyerano. Heinemann, Portsmouth

McCann JC (2011) The political ecology of cereal seed development in Africa: a history of selection. IDS Bulletin 42(4):24–35. doi:10.1111/j.1759-5436.2011.00233.x

McSweeney C, New M, Lizcano G (2012) UNDP climate change country profiles: Malawi. http://country-profiles.geog.ox.ac.uk/. Accessed 10 May 2014

Mertz O, Mbow C, Reenberg A, Diouf A (2009) Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. Environ Manage 43:804–816

Meze-Hausken E (2004) Contrasting climate variability and meteorological drought with perceived drought and climate change in northern Ethiopia. Clim Res 27:19–31

Moser SC, Ekstrom JA (2010) A framework to diagnose barriers to climate change adaptation. Proc Natl Acad Sci USA 107:22026–22031

Osbahr H, Dorward P, Stern R, Cooper S (2011) Supporting agricultural innovation in Uganda to respond to climate risk: linking climate change and variability with farmer perceptions. Exp Agric 47:293–316

Ovuka M, Lindqvist S (2000) Rainfall variability in Murang'a District, Kenya: meteorological data and farmers' perception. Geografiska Annaler Ser A Phys Geogr 82A:107–119

Patt AG, Schroter D (2008) Perceptions of climate risk in Mozambique: implications for the success of adaptation strategies. Glob Environ Change Hum Policy Dimens 18:458–467

Phiri IMG, Saka AR (2008) The impact of changing environmental conditions on vulnerable communities in the Shire Valley, Southern Malawi. In: Lee C, Schaaf T (eds) Future of drylands. Springer, Dordrecht

Prowse M (2009) Becoming a bwana and burley tobacco in the Central Region of Malawi. J Mod Afr Stud 47:575–602

Rao KPC, Ndegwa WG, Kizito K, Oyoo A (2011) Climate variability and change: farmer perceptions and understanding of intraseasonal variability in rainfall and associated risk in semi-arid Kenya. Exp Agric 47:267–291

Rickards L, Howden SM (2012) Transformational adaptation: agriculture and climate change. Crop Pasture Sci 63:240–250

Sanchez PA (2002) Ecology—soil fertility and hunger in Africa. Science 295:2019–2020

Scoones I, Thompson J (2011) The politics of seed in Africa's green revolution: alternative narratives and competing pathways. IDS Bull 42:1–23

Shiferaw B, Prasanna BM, Hellin J, Banziger M (2011) Crops that feed the world 6. Past successes and future challenges to the role played by maize in global food security. Food Secur 3:307–327

Silvestri S, Bryan E, Ringler C, Herrero M, Okoba B (2012) Climate change perception and adaptation of agro-pastoral communities in Kenya. Reg Environ Change 12(4):791–802. doi:10.1007/s10113-012-0293-6

Simelton E, Quinn CH, Batisani N, Dougill AJ, Dyer JC, Fraser EDG, Mkwambisi D, Sallu S, Stringer LC (2013) Is rainfall really changing? Farmers' perceptions, meteorological data, and policy implications. Clim Dev 5:123–138

Smale M (1995) Maize is life—Malawi delayed green-revolution. World Dev 23:819–831

Tadross M, Suarez P, Lotsch A, Hachigonta S, Mdoka M, Unganai L, Lucio F, Kamdonyo D, Muchinda M (2007) Changes in growing-season rainfall characteristics and downscaled scenarios of change over southern Africa: implications for growing maize. IPCC regional Expert Meeting on Regional Impacts, Adaptation, Vulnerability, and Mitigation, Nadi, Fiji

Toenniessen G, Adesina A, Devries J (2008) Building an alliance for a green revolution in Africa. Reducing Impact Poverty Health Hum Dev Sci Approaches 1136:233–242

Tripp R, Rohrbach D (2001) Policies for African seed enterprise development. Food Policy 26(2):147–161. doi:10.1016/s0306-9192(00)00042-7

Wang YM, Namaona W, Traore S, Zhang ZC (2009) Seasonal temperature-based models for reference evapotranspiration estimation under semi-arid condition of Malawi. Afr J Agric Res 4:878–886

Whitfield S, Kristjanson P (2014) Envisaging change in maize farming: the push and pull factors. Climate Change and Social Learning Brief No 4. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Copenhagen, Denmark

Yaro JA (2013) The perception of and adaptation to climate variability/change in Ghana by small-scale and commercial farmers. Reg Environ Change 13(6):1259–1272. doi:10.1007/s10113-013-0443-5

Yuksel N (2008) Achieving a uniquely African green revolution. http://www.future-agricultures.org. Accessed 23 July 2015

Zampaligre N, Dossa LH, Schlecht E (2014) Climate change and variability: perception and adaptation strategies of pastoralists and agro-pastoralists across different zones of Burkina Faso. Reg Environ Change 14:769–783